University of Verona,
School of Exercise and Sport Science,
Laurea magistrale in Scienze motorie preventive ed adattate

Metodologia delle misure delle attività sportive

Wednesday 30/10/2013

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A class within a four classes module

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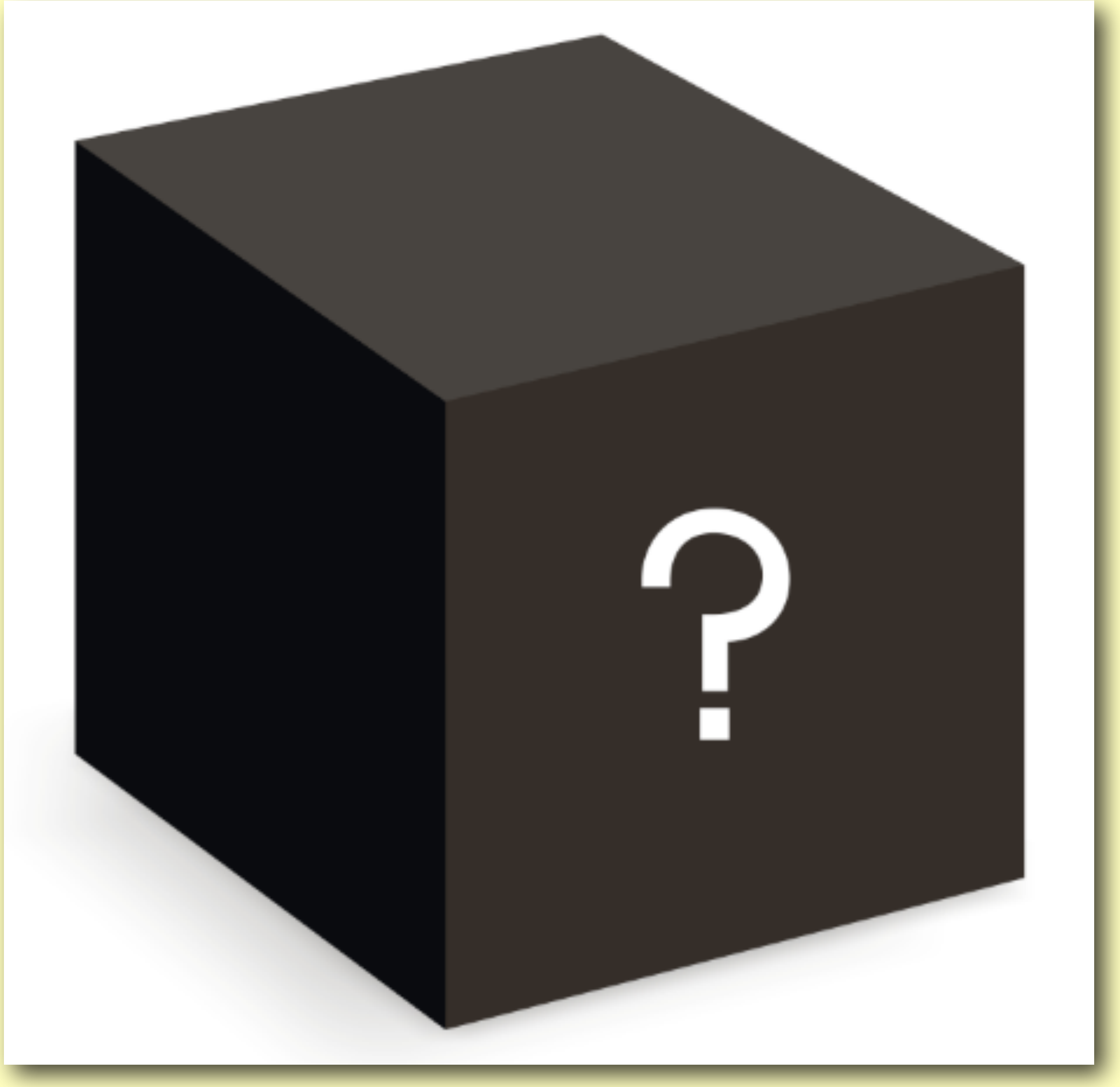
Accelerometer

Accelerometer issues

- PROPRIETARY ALGORITHM (i.e., ‘how from count to ME?’);
- need for custom developed software…



Accelerometer

Accelerometer issues

- From linear to non-linear ME=f(counts) -> 3D accelerom. -50->-3% nME

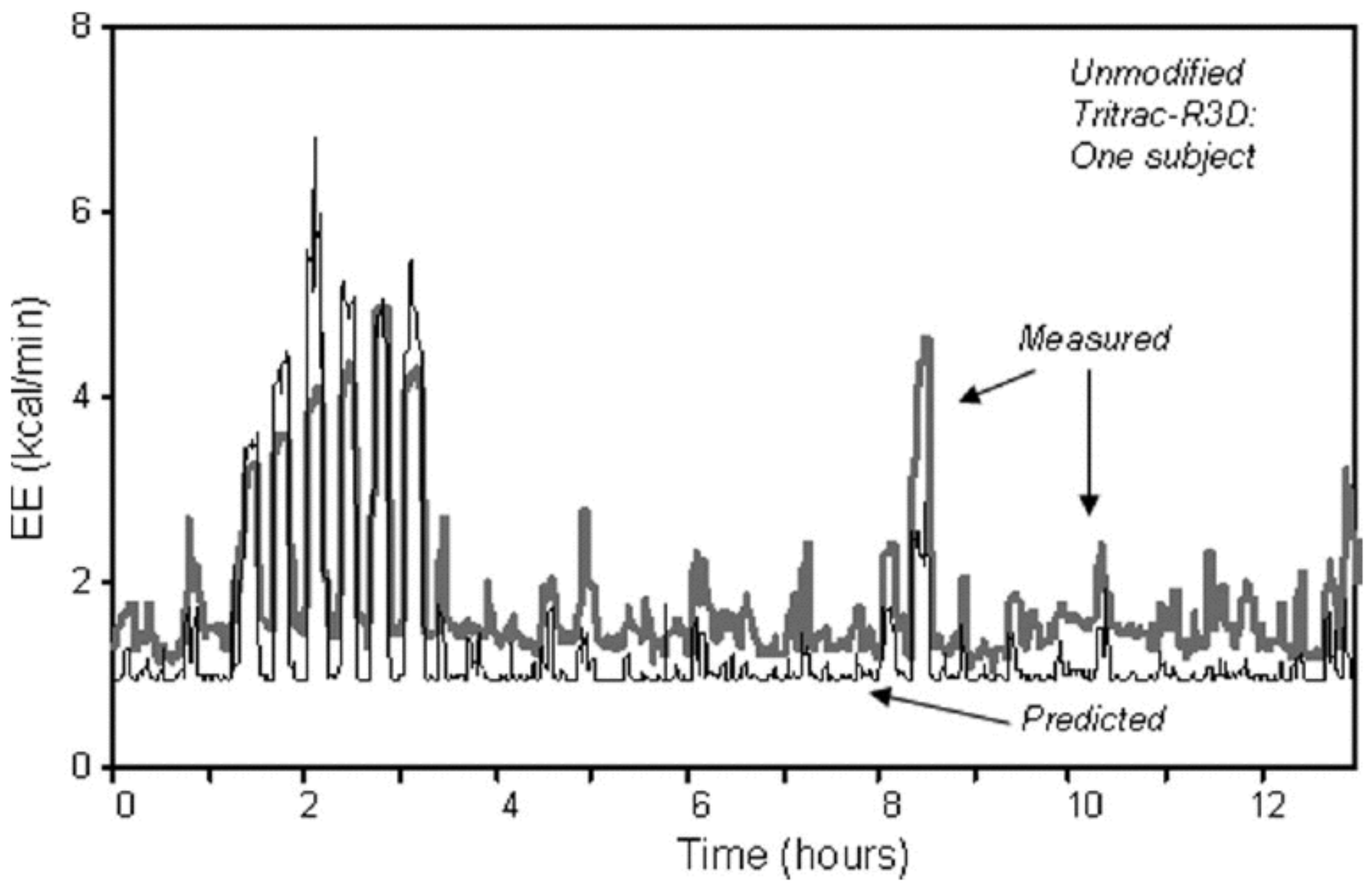


FIGURE 4—Subject: a woman age 32 yr, body mass 67.4 kg, resting EE = 1.06 kcal·min^{-1}. Tritrac-predicted EE (*thin black line*) vs the calorimeter-measured EE (*thick black line*) during the waking period of a 24-h stay in the room calorimeter. r = 0.88, SEE = 0.48 kcal·min^{-1}.

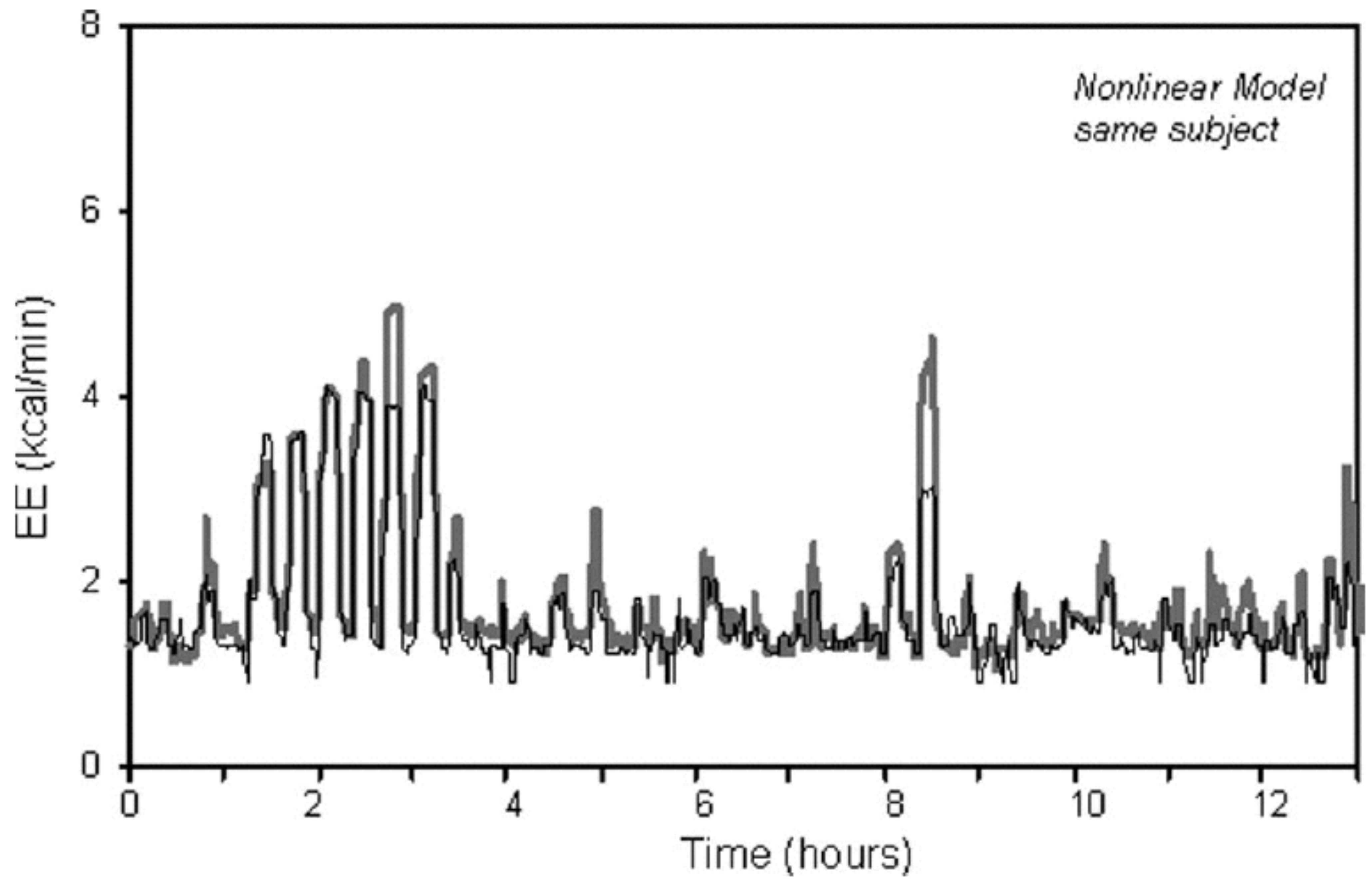


FIGURE 5—.Same subject as in Figure 4. Predicted EE using the modified two-component nonlinear model (*thin black line*) vs the calorimeter-measured EE (*thick black line*). r = 0.94, SEE = 0.27 kcal·min^{-1}.

Chen et al., 2005

Accelerometers

Caltrac 

-> TriTrac-R3D -> RT3 

ActiGraph 71-64/-256  -> ActiGraph GT1M 

->

-> ActiGraph GT3X 

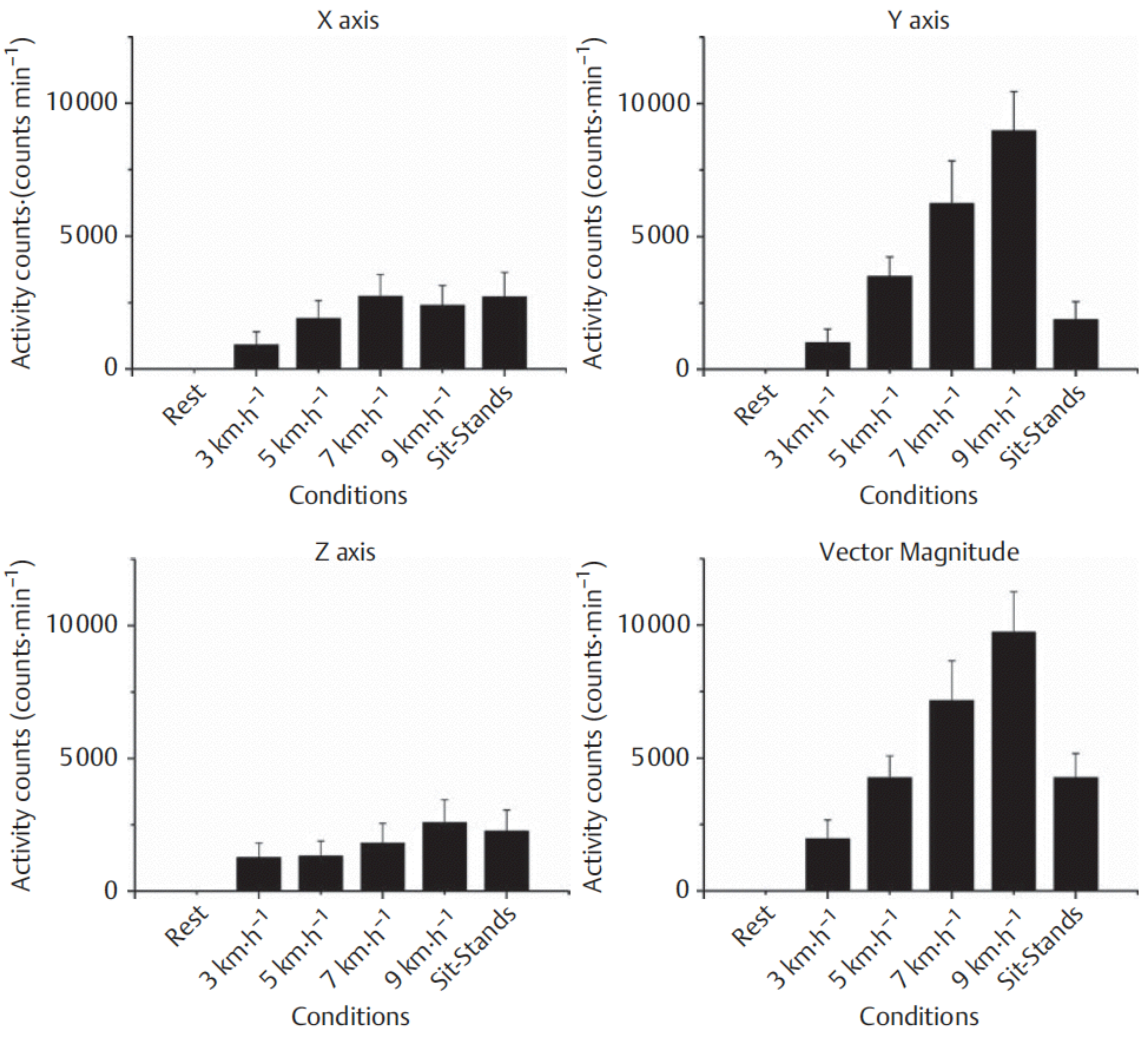


Fig. 1 Activity counts (counts · min^{-1}) (mean ± standard deviation) per axis and activities for all participants.

Santos-Lozano et al., 2013

Accelerometers

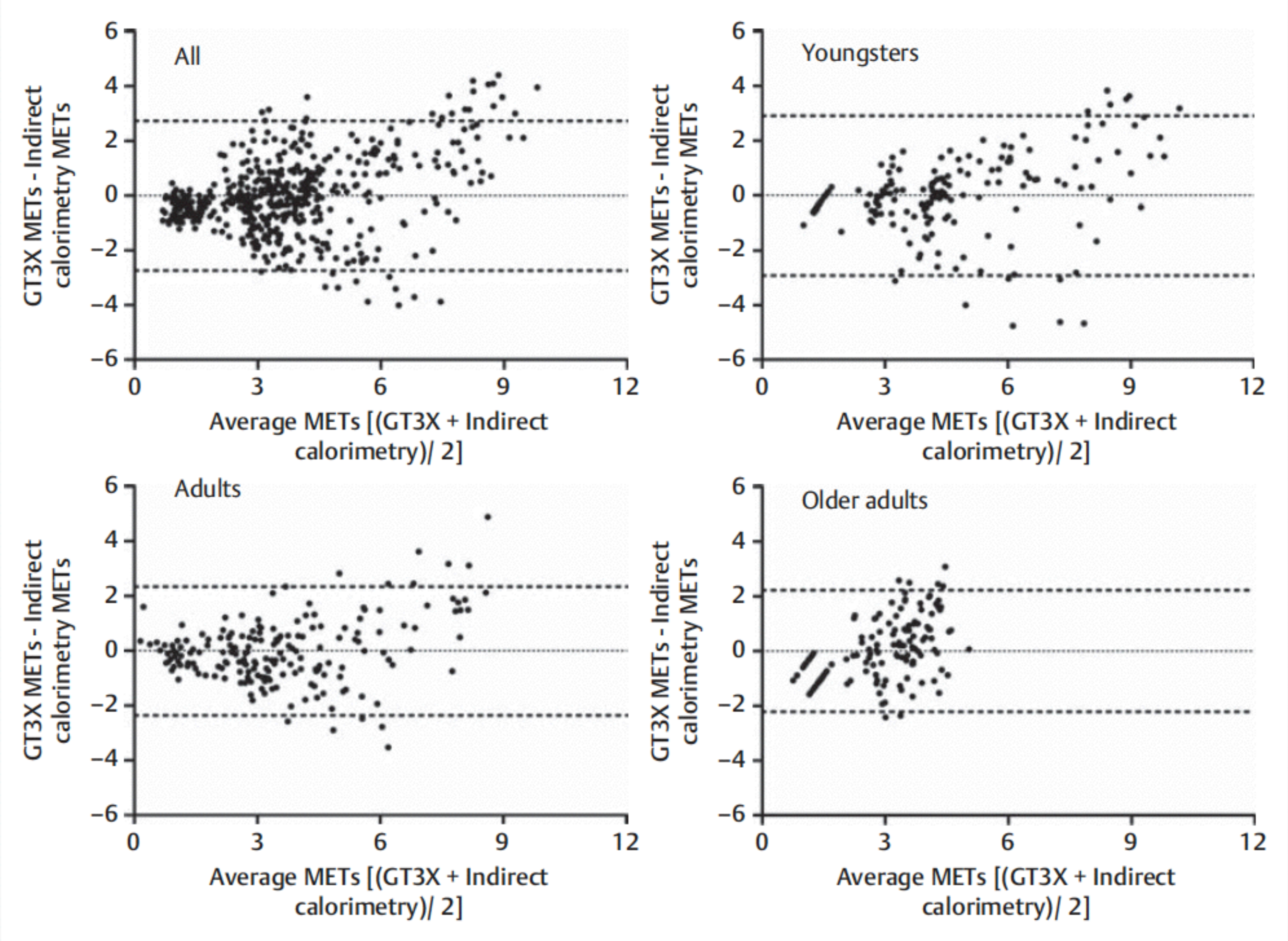


Fig. 3 Bland and Altman Plots in each group (energy expenditure (EE, in METs) determined with indirect calorimetry – EE (METs) predicted with GT3X).

Santos-Lozano et al., 2013

Accelerometers

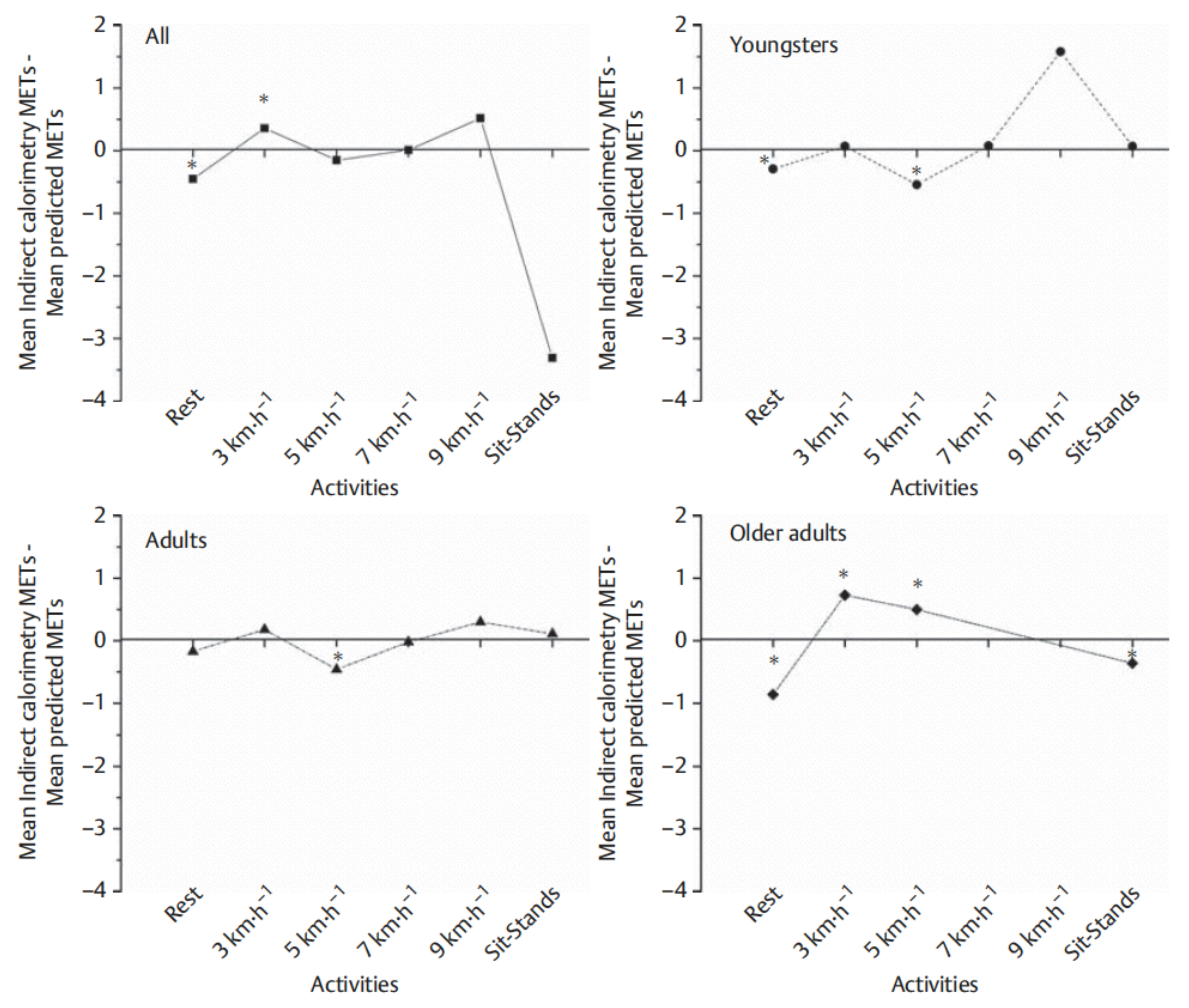


Fig. 4 Energy expenditure (EE, in METs) from indirect calorimetry vs. EE predicted with the GT3X for each age-group. *Significantly different from indirect calorimetry vs. predicted, same activity and age-group, $P<0.05$.

Santos-Lozano et al., 2013

Accelerometers

Actiwatch

-> Actical

Actitrac

Biotrainer

Accelerometers

Nokia N79

Carlson Jr et al., 2012

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Accelerometers

measures

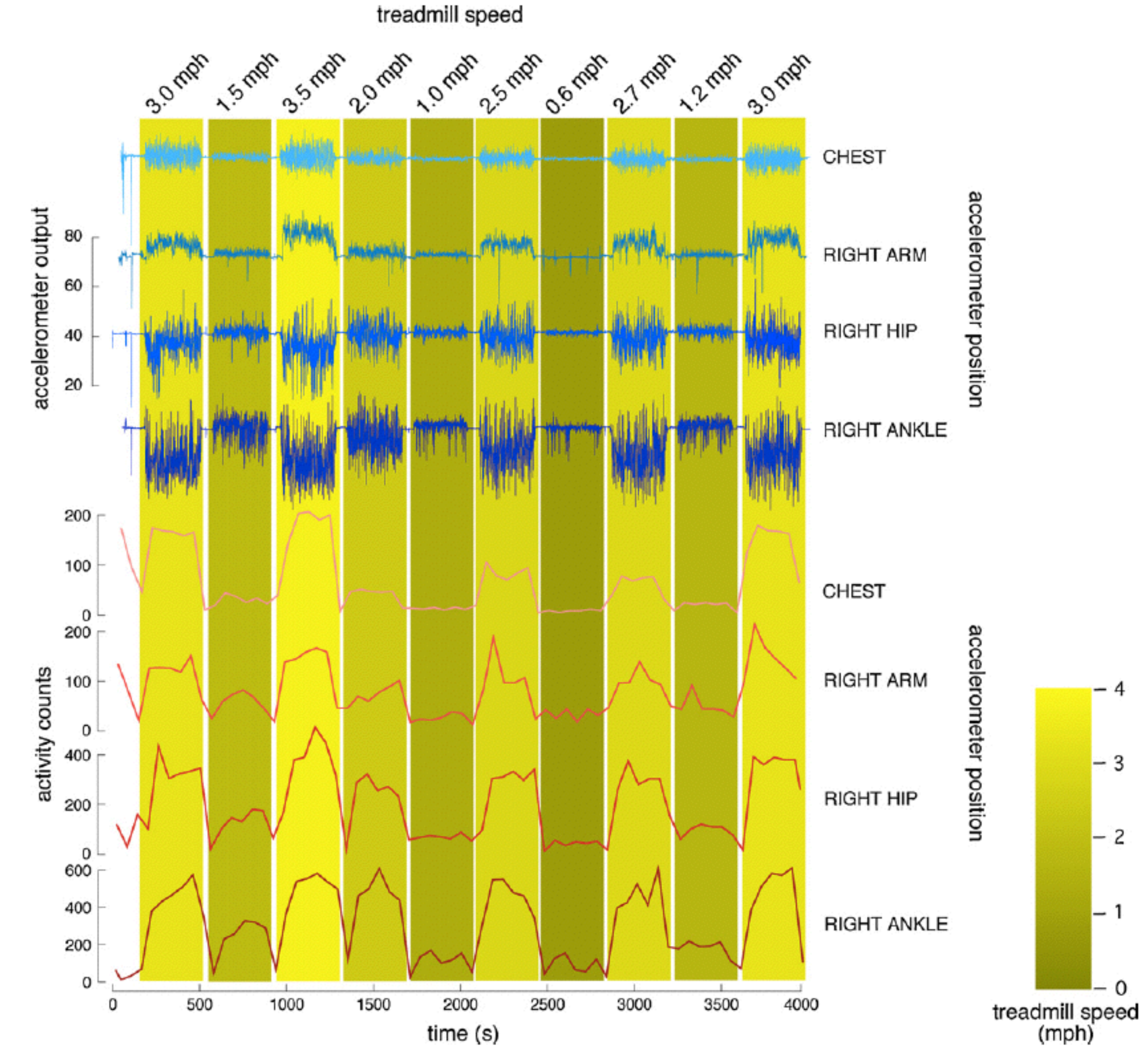

Fig. 1. Activity counts from cell-phone accelerometers provide an accurate measure of treadmill gait speed regardless of where the sensor is worn. The top four traces depict raw data from a representative trial (43 y/o man) showing acceleration magnitude *versus* time for sensors worn at the chest, right arm, right hip, and right ankle (1st through 4th traces from top, respectively). For all traces the baseline is centered at 64 (midscale between sensor output of 0 for −2 g, and 128 for +2 g), the amount of deflection from this baseline is per the common scale provided left of these traces. The bottom four traces show activity counts *versus* time for the sensors worn at the chest, right arm, right hip, and right ankle, respectively. Counts were calculated over 1 min nonoverlapping bins. Treadmill speed is given at the top of each epoch bar.

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Accelerometers

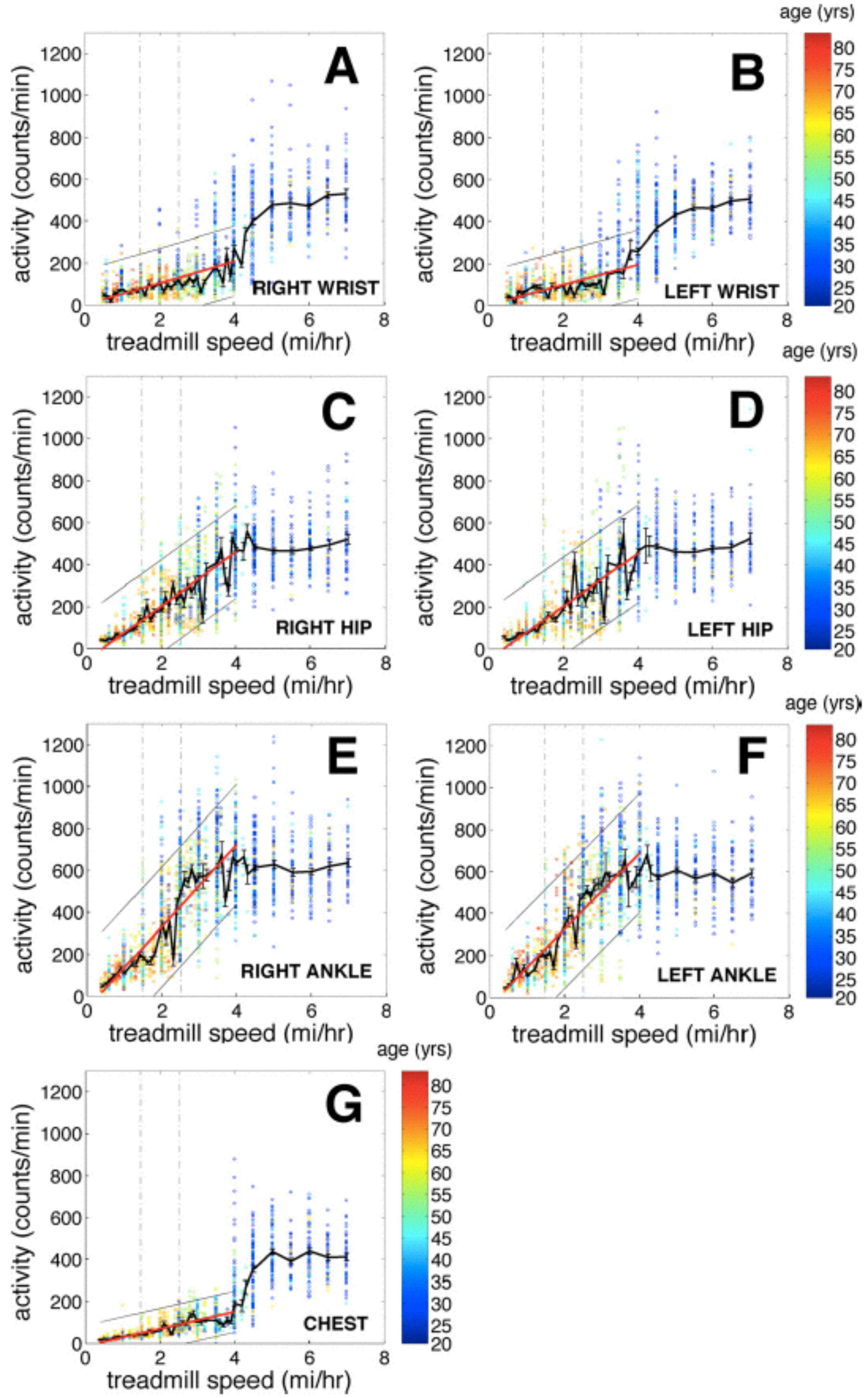

Fig. 3. Activity count versus treadmill speed relationships for all sensor locations. For all figures, the solid red line shows the linear regression between treadmill speed and activity counts (fit for all data between 0.0 and 6.4 km/h (0–4 mi/h) gait speeds); the thin surrounding black lines are 95% confidence boundaries on this regression. The thick black line connects mean activity count values for each of the evaluated treadmill speeds; bars surrounding this point are ±1 standard error of the mean. Individual observations of activity counts are shown as open colored circles. Subject age is color coded as circle color; refer to colorbar at right side for key. The dashed lines at gait speeds of 2.35 km/h (1.46 mi/h) and 4 km/h (2.5 mi/h) highlight system performance at two critical functional thresholds. These relationships come from cell phones placed at the right wrist (A), left wrist (B), right hip (C), left hip (D), right ankle (E), left ankle (F), and neck (G).

DLW method

- Lifson et al., 1955;
- (small animals) 1975;
- validation by Scholler et al., 1982;
- (premature infants, children, pregnant and lactating women, elderly, obese people, hospitalized patients);
- subject is administered a dose of stable isotope $^{2}H_2{}^{18}O$, which (^{2}H, ^{18}O) equilibrates relatively quickly with body water (H, O);
- ^{2}H is eliminated as $^{2}H_2O$ (breath, urine, sweat, perspiratio insensibilis), while the ^{18}O is eliminated either as $H_2{}^{18}O$ (breath, …) and as $C^{18}O_2$ (breathe only);
- difference between the two rates of elimination -> V'CO2 -> ME

DLW method

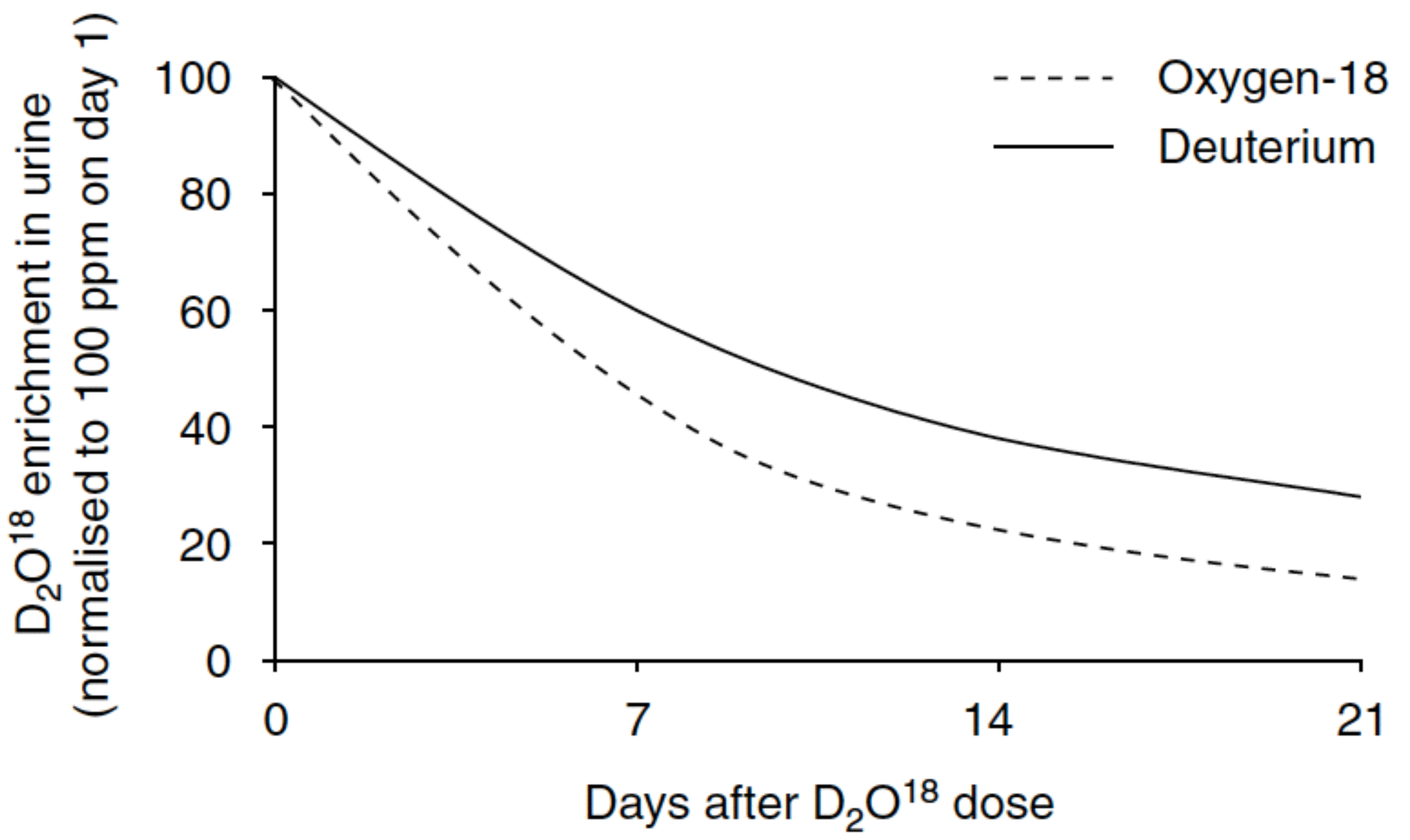

Fig. 1. Decline of ^{2}H (deuterium [D]) and ^{18}O in body fluids (urine, plasma or saliva) during a hypothetical doubly labelled water experiment.

DLW method

- RQ (= V'CO2 / V'O2) estimate -> reliability:
    . standard Western diet -> RQ estimate;
    . food intake diary -> RQ estimate (i.e., food quotient ≈ RQ);
    . indirect calorimetry -> RQ

DLW method

DLW method issues

- inability to discriminate the contribution of individual PAs (types, amount, intensity of each type) to ME;
- costs: isotopes and tools to detect them (i.e., mass spectrophotometers) still have considerable costs;
- -> only 3-4 ÷ 21 d ME;
- unknown RQ -> 5% e

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DLW method

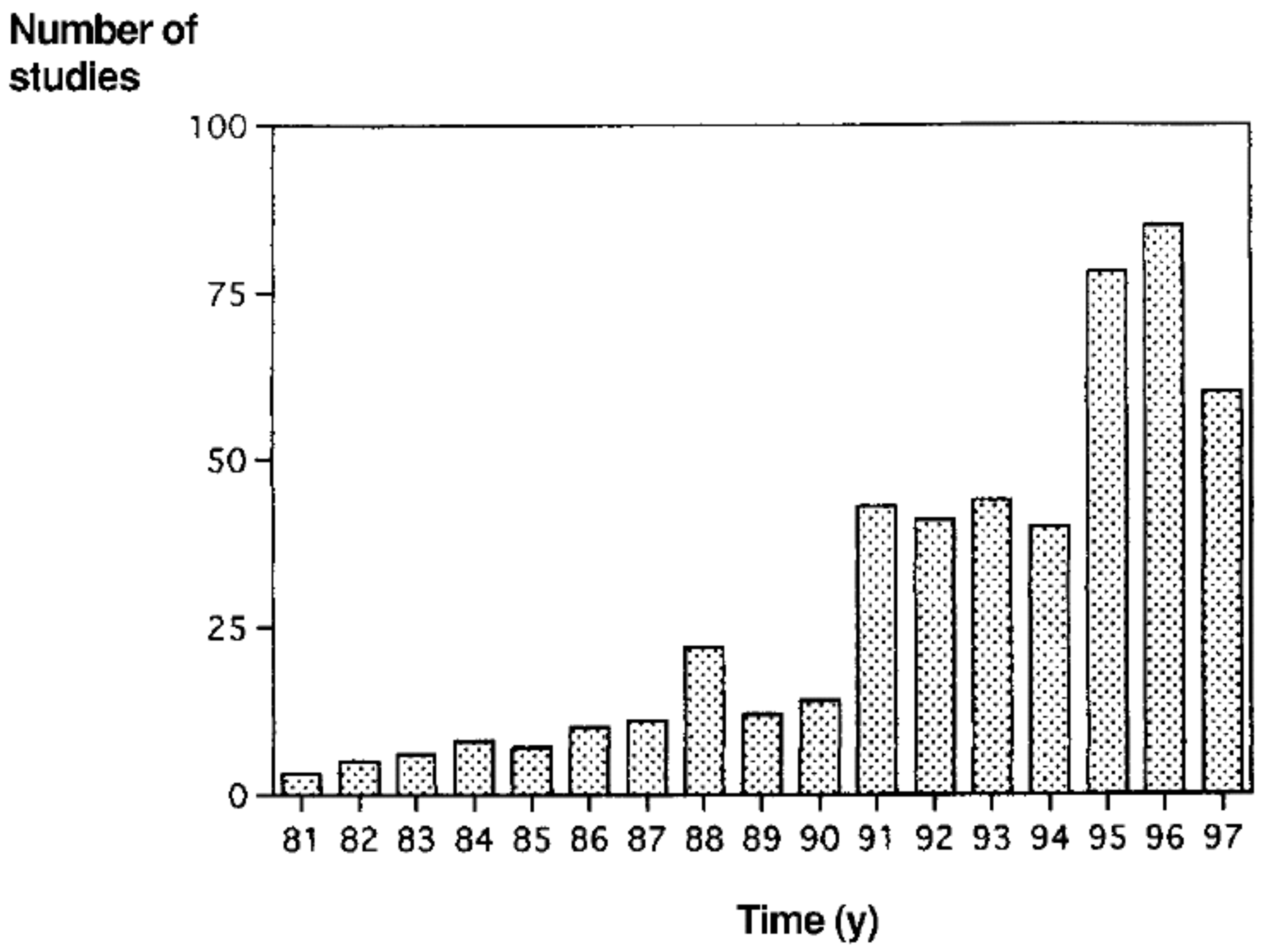

FIGURE 1. Number of studies in peer-reviewed journals (excluding abstracts) that used the doubly labeled water technique in the years 1981–1997 (through June) from the *Science Citation Index* (Institute for Scientific Information, University of Aukland, New Zealand). Since the first study in humans in 1982 the use of the technique has continued to grow.

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Second generation accelerometers

Accelerometer issues

- SINGLE-SITE PLACEMENT;
- waist placement -> PA underestimate during upper limb movement, standing, vertical activity (i.e., climbing stairs, uphill walking), pushing or pulling objects, carrying loads (e.g., books or laptops), body-supported exercise (e.g., cycling), water PA (e.g., swimming), running faster than 9 km/h, horizontal speed rapid changes activities (e.g., tennis)

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Second generation accelerometers

Solution?

- A combination of variables describing:
  1) upper limbs-focused high frequency components (upper limbs movements feature sedentary PA);
  2) a trunk-focused posture variable featuring locomotion;
  3) lower limbs-focused high intensity components (lower limbs have largest, most powerful muscles);

Second generation accelerometers

- More than ONE accelerometer together, as well
  (e.g., waist TriTrac-R3D + dominant arm wrist Actiwatch, Actiwatch + Actical, ...);
- accelerometers based activity logger:
  . two (@sternum, front thigh) biaxial accelerometers + analog data-logger;

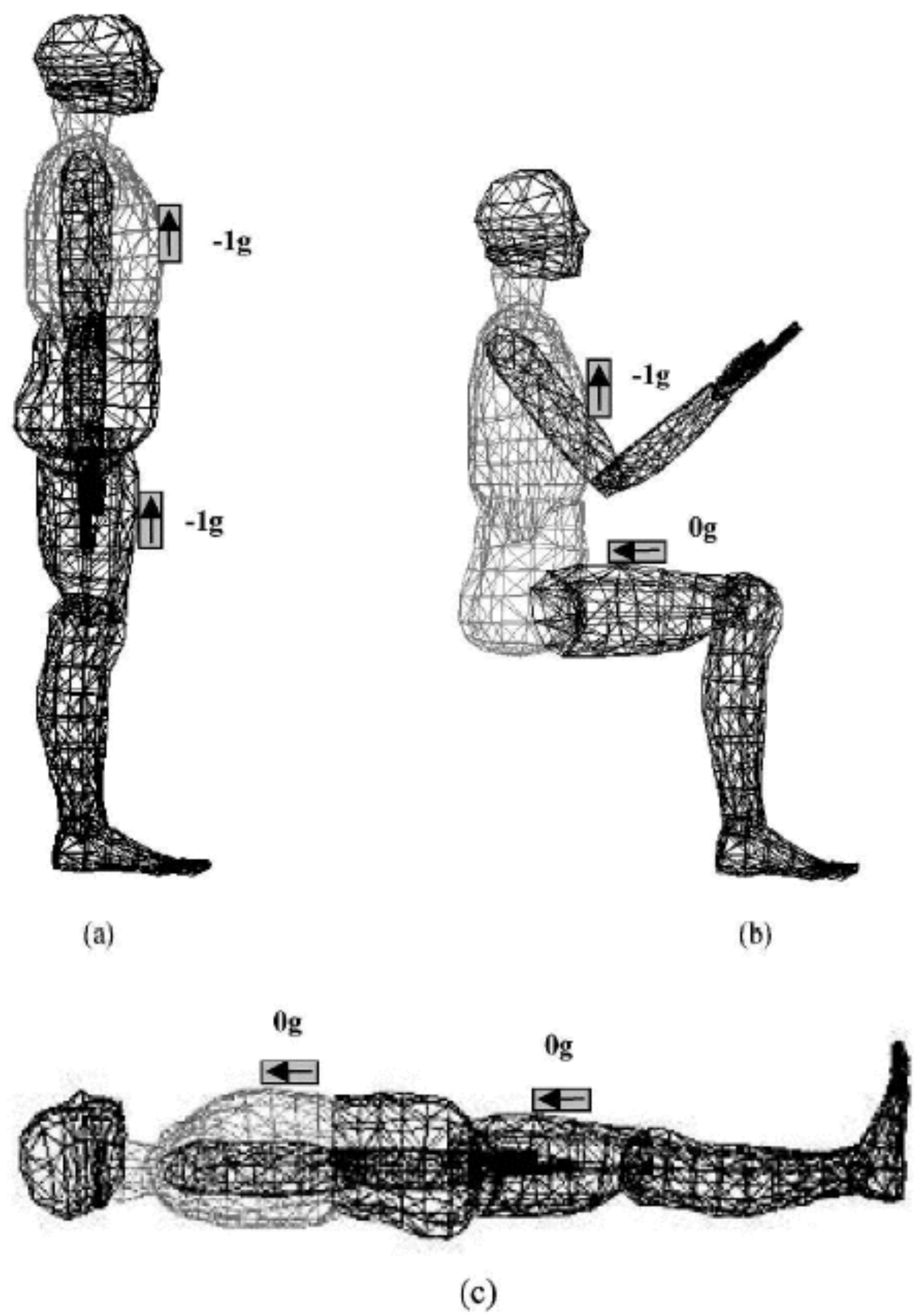

Figure 1 Discriminating postures: (a) standing, (b) sitting, (c) lying. The arrows indicate the investigated direction of the active axis of the accelerometers. The acceleration values correspond to the accelerometer output at each orientation in units of ***g***.

Culhane et al., 2004 66

Second generation accelerometers

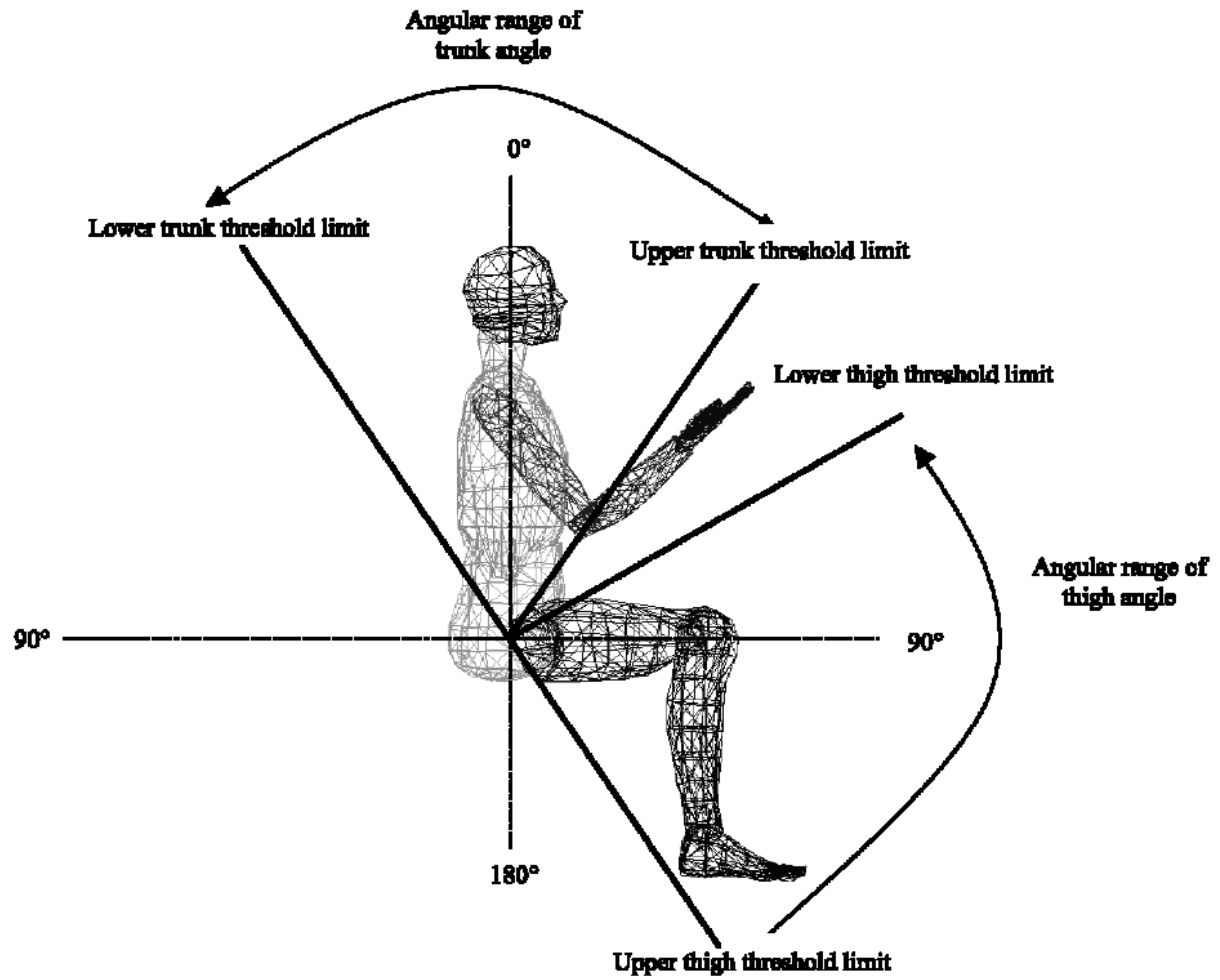

Figure 2 Sitting criteria.

Culhane et al., 2004

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Second generation accelerometers

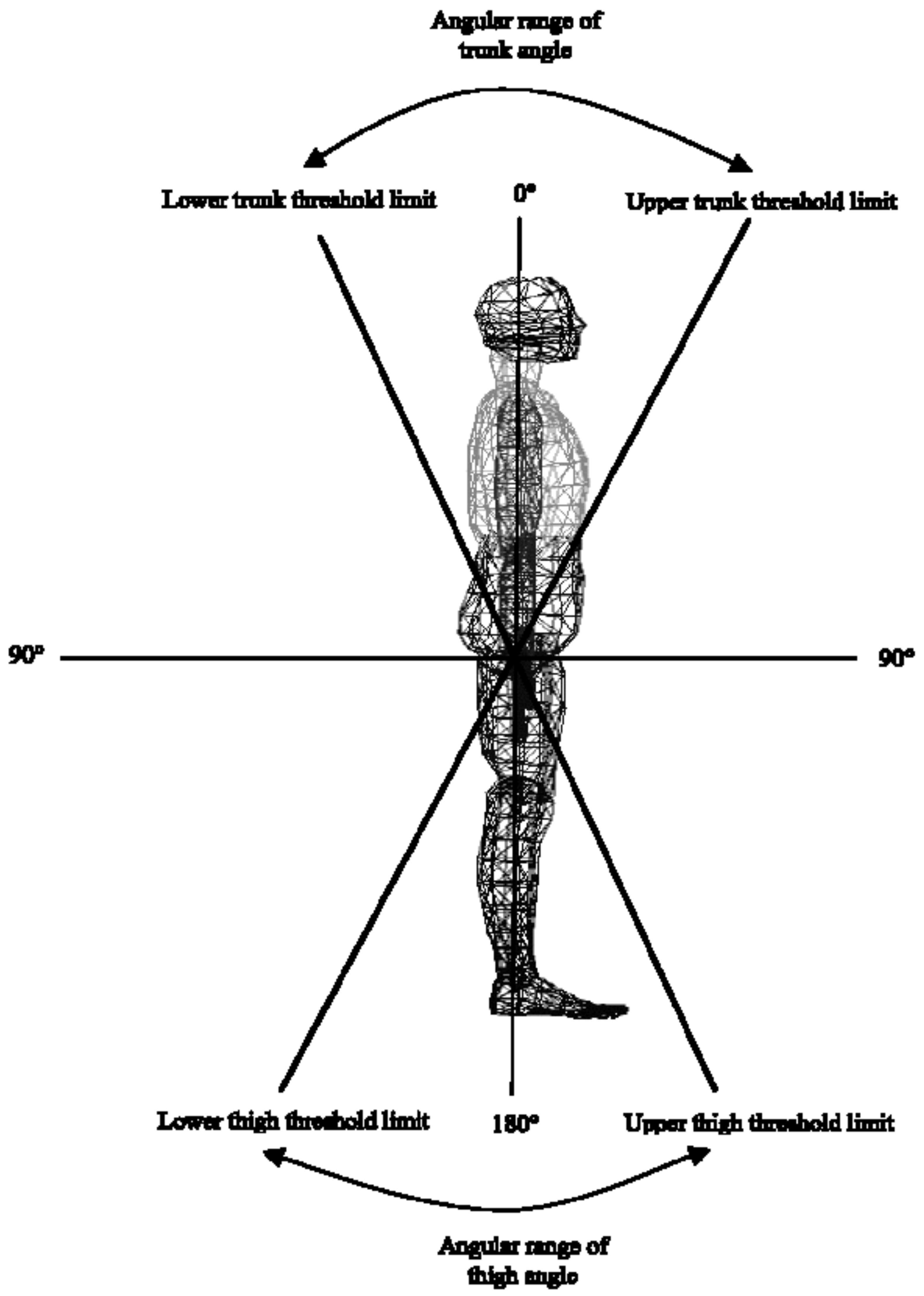

Figure 3 Standing criteria.

Culhane et al., 2004

Second generation accelerometers

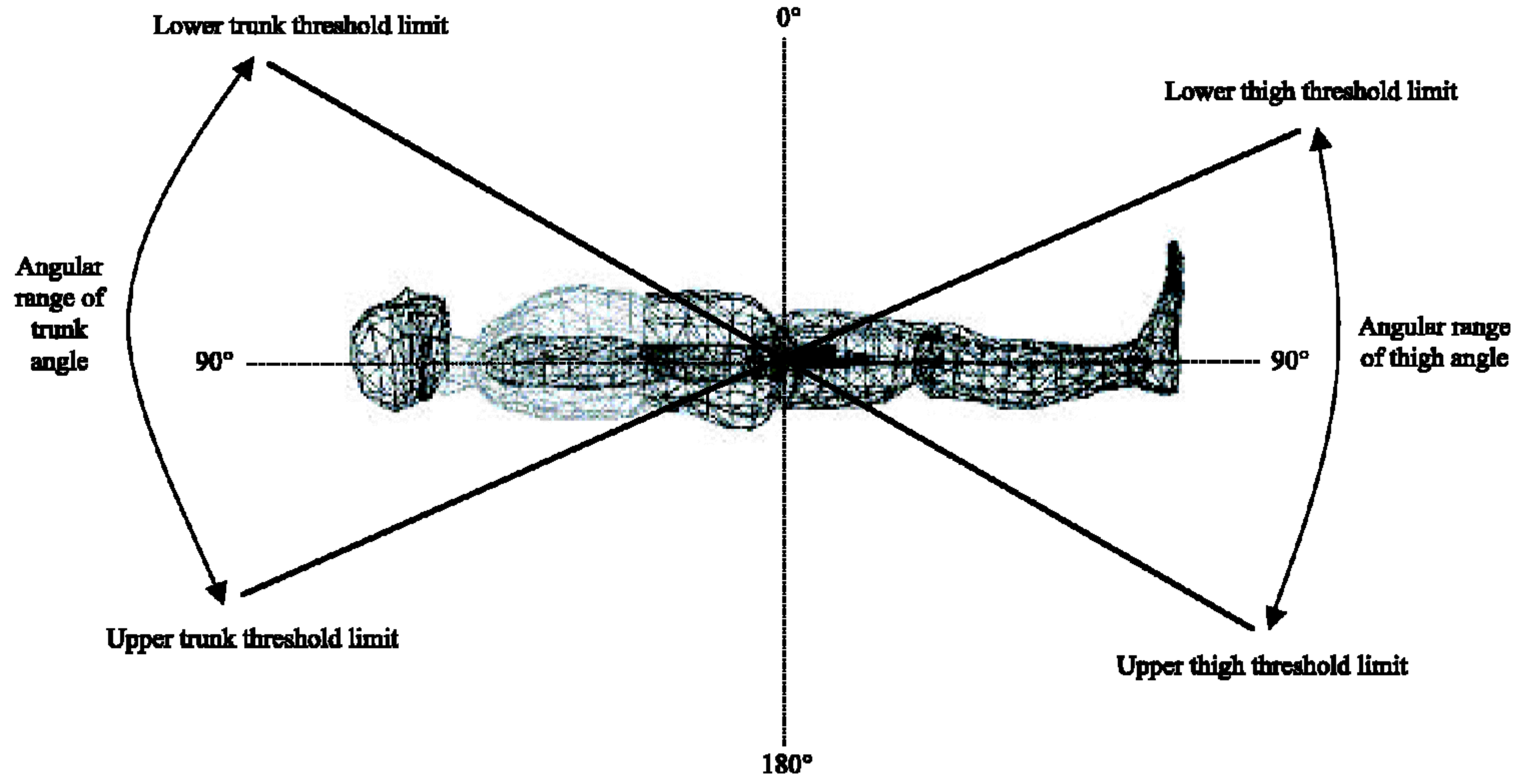

Figure 4 Lying criteria.

-> sitting, standing, lying, moving 83% detection;

Culhane et al., 2004

Second generation accelerometers

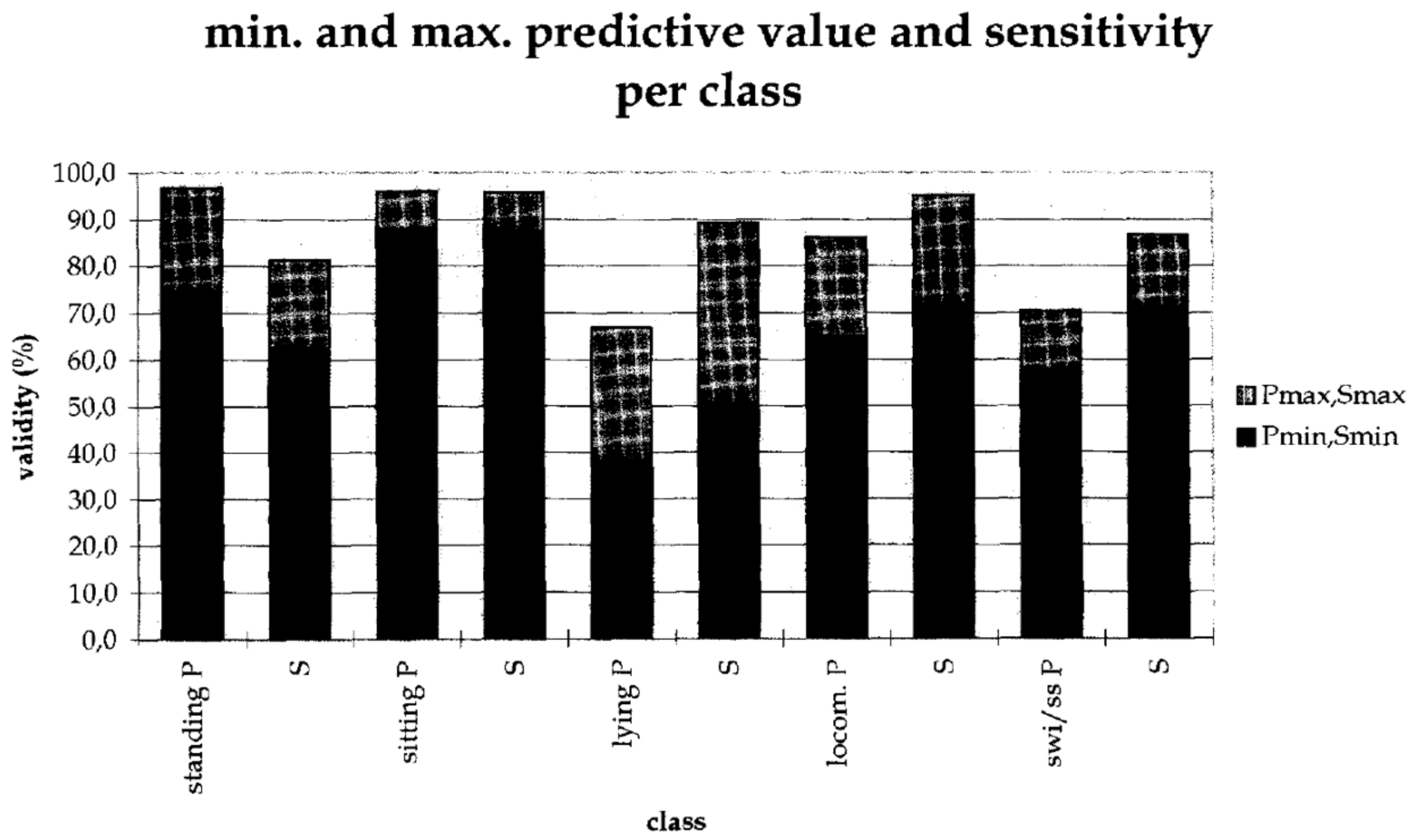

Figure 6 Minimal and maximal validity of the individual ADL categories based on the monitor's sensitivity (S_{min} and S_{max}, respectively) and predictive value (P_{min} and P_{max}, respectively). Sensitivity indicates how often the monitor recognizes a category; the predictive value indicates how often the decision of the monitor is correct. A lack of sensitivity indicates a false negative; a lack of predictive value indicates a false positive.

Busser et al., 1997

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. uniaxial accelerometer (@front thigh) + 2 unixial accelerometer/digital data-logger (backpack)
-> sitting, standing, lying, crawling, walking, running, going on a swing 73÷91% detection;

Second generation accelerometers

. three uniaxial accelerometers (2@sternum, front thigh) + digital recorder;
-> sitting, standing, lying, walking, climbing/going down stairs, cycling 80% detection (Veltink et al., 1996);
. four biaxial accelerometers (@lateral thighs, sternum or front forearms) + HR monitor + digital recorder;
-> more than twenty different postures/locomotions 83÷88% detection;

Figure 1. An extended configuration of the Activity Monitor, with accelerometers at the thighs, trunk, and lower arms.

Bussmann et al., 2001

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Second generation accelerometers

- Introduction of another type of physical sensor:
  . (@sternum) two biaxial accelerometers + piezoelectric gyroscope + digital recorder (@wrist);

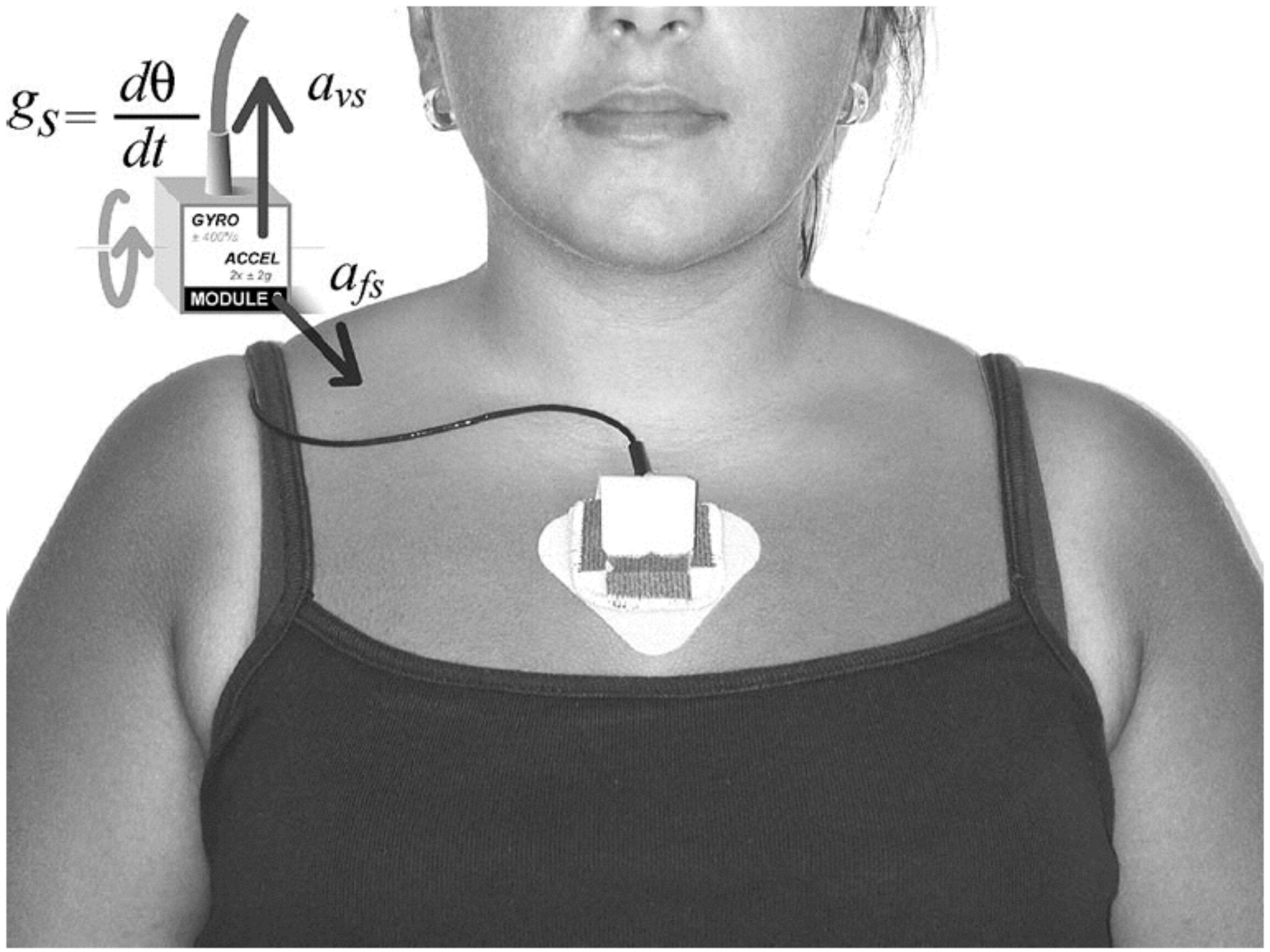


Fig. 1. Sensor attachment. Vertical and frontal acceleration (a_{vs} and a_{fs}) as well as angular velocity (g_s) are measured using a kinematic sensor attached to the subject's chest.

Najafi et al., 2003

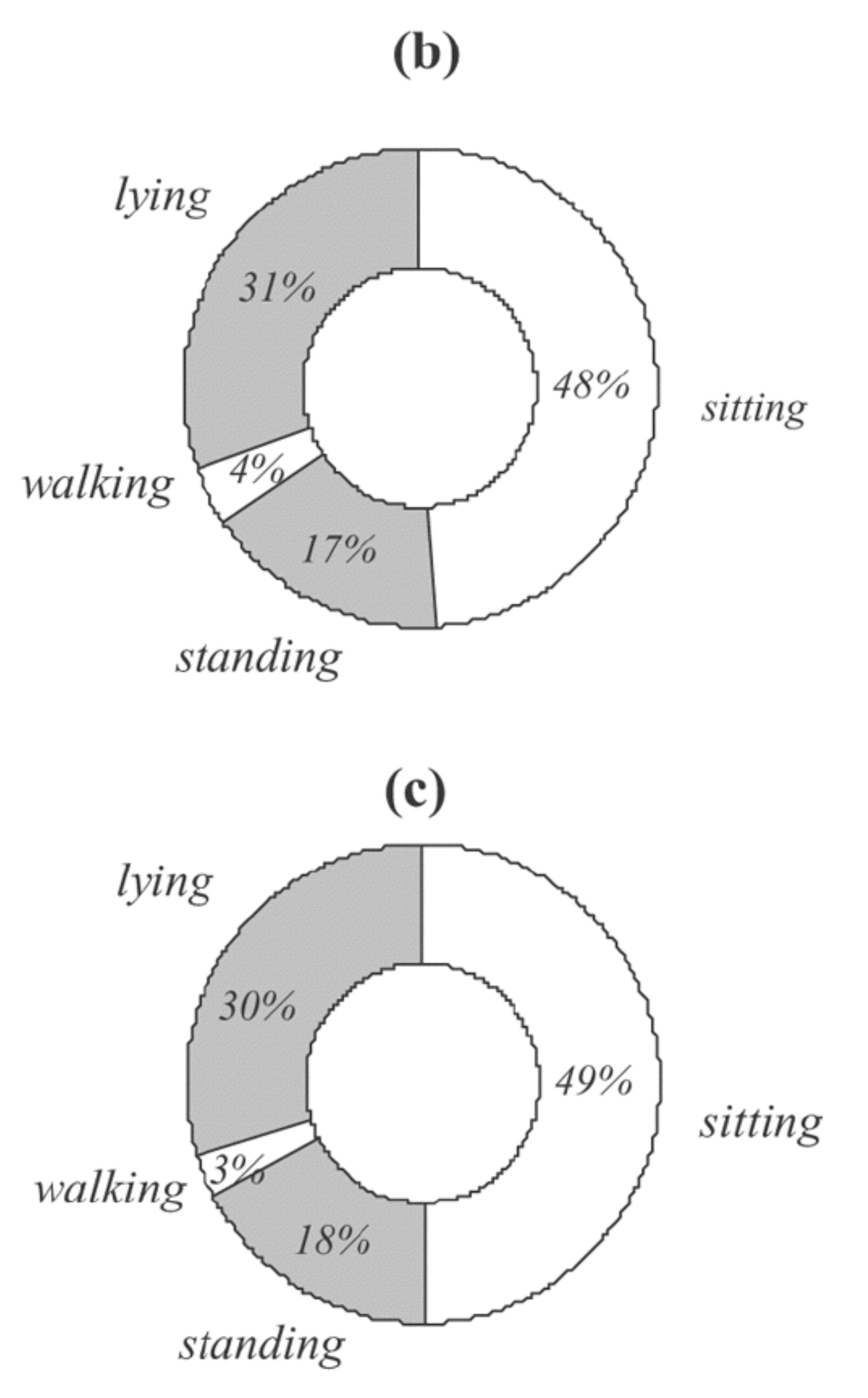
Second generation accelerometers

measures

TABLE II
OVERALL SENSITIVITY AND SPECIFICITY OF TRANSITION DETECTION FOR THE 11 ELDERLY (FIRST STUDY)

# Test	Total PT*	Sensitivity, %					Specificity, %	
		PT	SiSt**	StSi	Lying	Walking	SiSt	StSi
1	40	100	100	100	100	95±4	100	100
2	66	98±5	100	97±10	-	97±3	95±12	100±0
3	58	100	97±10	63±29	-	-	63±29	97±10
4	58	100	88±25	75±29	-	-	75±29	88±25
5	64	96±9	89±18	86±19	-	-	86±19	94±13
6	57	100	85±19	72±24	-	-	72±24	85±19
Mean	***57±9***	***99±2***	***93±7***	***82±15***	***100***	***96±1***	***82±15***	***94±6***

* PT: Postural transition.
** SiSt: sit-to-stand transition.
† StSi: stand-to-sit transition.



Najafi et al., 2003

-> posture change, walking detection;

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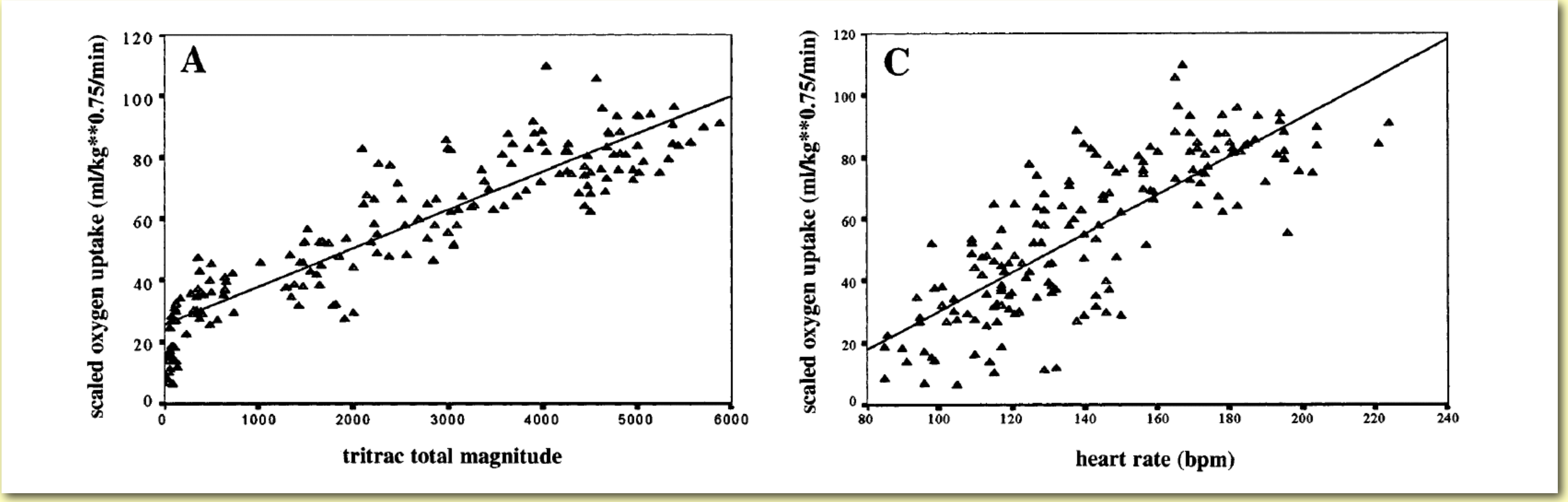
Second generation accelerometers

- Accelerometry (-> movement) + physiological measure (e.g., HR measure, thermometry, ventilation measure):
  . e.g., HR monitor (-> ME) + motion sensor(s) (-> motion-sensor-sensitive PA);
- accelerometers + inclinometers -> body position over time -> 85% unstructured exercise thermogenesis estimate:
  . total internal heat produced ≈ 75÷80% energy intake;
  . partial internal heat produced <- sitting, standing, walking, working, any other unstructured exercise;
  . proposal: (during the day) wearing motion sensor, (structured exercise) wearing HR monitor;
  . i.e., motion sensor -> yes/not time to use HR monitor for ME estimate;

Second generation accelerometers



Eston et al., 1998

. exception: children (i.e., V'O2 [ml O2/kg.75 min] correlated w/both counts, HR, but w/counts r^2 > w/HR r^2);

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Second generation accelerometers (re: children HR)

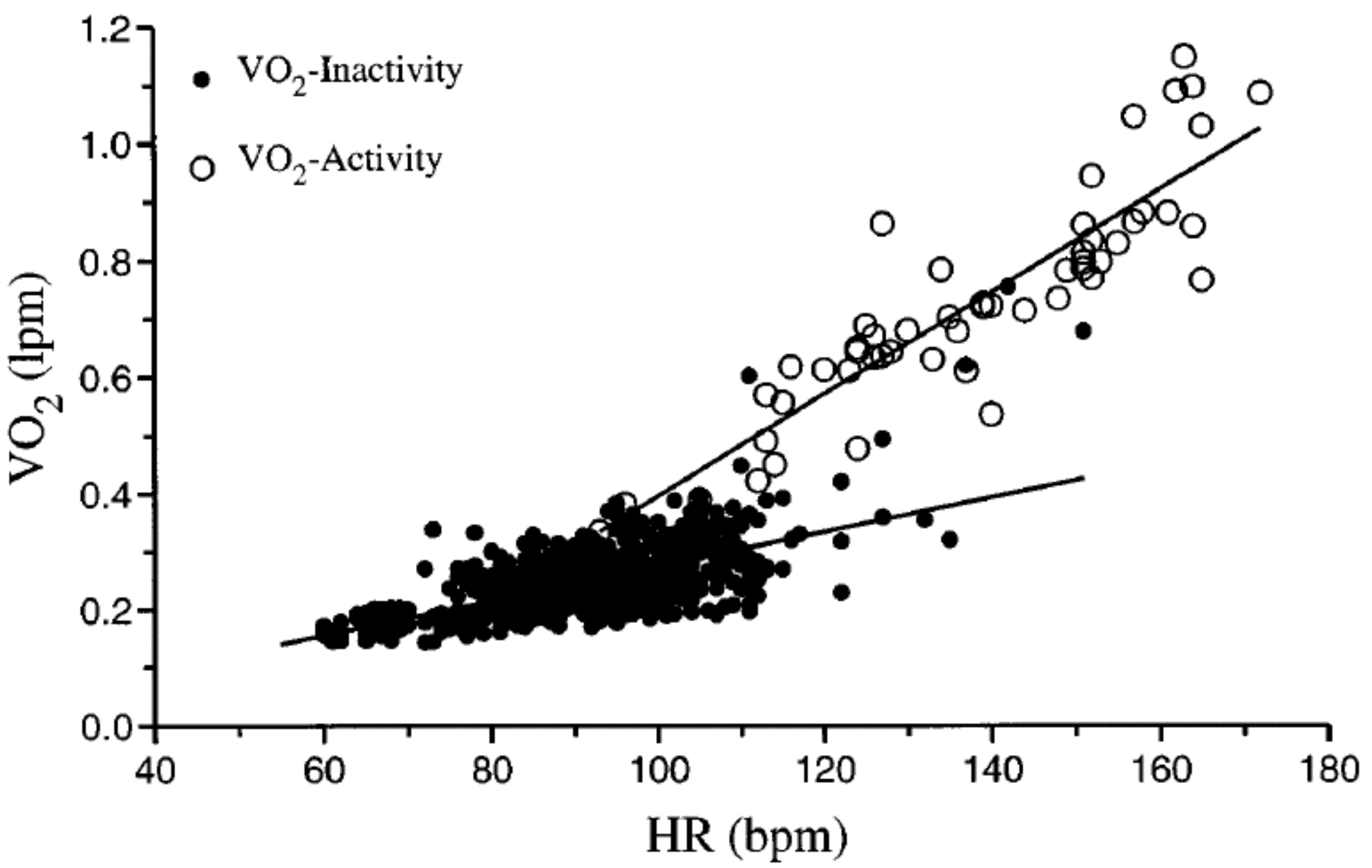

Fig. 1. Oxygen consumption ($\dot{V}O_2$) and heart rate (HR) relationship in the room calorimeter for one subject, with separate curves for active vs. inactive data for awake portion of the day (*method 3*).

Treuth et al., 1998

. solution: two different individual V'O2 vs. HR relationships, one for inactivity, one for PA;

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Second generation accelerometers

- Accelerometry + HR measure:
  . FitSense FS-1;
  . Actiheart:
    - @chest;
    - each subject's calibration;
    - OPEN ALGORITHM;
    - user's models;
    - accelerometer-, HR monitor-, accelerometer+HR monitor-driven model;

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Second generation accelerometers

. SenseWear Armband:

- accelerometer + heat flow sensor (-> ‘internal heat produced’) + skin galvanic response sensor (-> evaporation heat loss) + skin thermometer + instrument’s shell (i.e., near-body) thermometer;
- gender, age, height, mass input;
- PROPRIETARY ALGORITHM (I.E., ‘HOW FROM EACH SENSOR’S OUTPUT TO ME?’);

-> -18÷-7% walking, stairs climbing, cycling V’O2 ME;

-> -29% armergometer V’O2 ME;

<- investigators results driven new PROPRIETARY algorithm developed -> n.s. differences;

-> underestimate of rowing V’O2 ME;

arm cutaneous fat issue;

-> good precision of resting V’O2 ME;

-> good precision/low accuracy of cycloergometer V’O2 ME;

Second generation accelerometers

-> +13÷+27% level walking V'O2 ME;
-> -22% uphill walking V'O2 ME;
-> overestimate of walking, running V'O2 ME;
-> overestimate of wheelchair users activities V'O2 ME;
-> underestimate of obese subjects resting V'O2 ME;
-> overestimate of obese subjects exercise V'O2 ME;
-> good accuracy of daily DLW ME;
-> underestimate of uphill walking, running V'O2 ME

Global Positioning System

- Global Positioning System (GPS) is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites;
- provides critical capabilities to also commercial users around the world;
- is maintained by the USA government and is freely accessible to anyone with a GPS receiver;